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SOME
FURTHER ILLUSTRATIONS
OF THE
SAFETY-VALVE FUNCTION
OF
THE HEART.

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THE theory of a safety-valve function in the circulation of man, and of warm-blooded animals generally, is, I think, to be supported by as great a variety and strength of argument as any of the doctrines of physiology. The nature of the evidence has formerly been pretty fully indicated\*; and the view then unfolded can scarcely be said to have met with a less favourable reception than was to have been reasonably anticipated: yet it cannot be thought unnecessary to add fresh illustration to so novel a topic†. I have persuaded myself, that the importance of the subject to the naturalist, but more especially to medical men, ought to be more than an excuse for the attempt to extend and illustrate the theory, by every possible source of knowledge directly bearing on the subject. It is perhaps rather to be regretted, that, in the way of pathology, so little has been done to render the exposition practically available. The pathology of the right side of the heart, and of its safety-valve, would be topics

\* See Hospital Reports, Vol. II. p. 104.

† I have formerly quoted all I know of the expressions which only approach the idea of a safety-valve. I do not suppose that Dr. Adams will think it otherwise than just, to say that he has not attempted to demonstrate the existence of a safety-valve, and that he has not hinted at the arrangements on which regurgitation depends. I am not aware that he did any more than express his opinion that there is in the right side of the heart “a natural provision to allow of a partial reflux into the right auricle;” saying, it “was absolutely necessary,” “as various natural causes must momentarily retard the passage of blood through the lungs.”

I have thought it reasonable to make this remark, in consequence of observing that more appears to be attributed to Dr. Adams than I suppose he has ever laid claim to.

of easy discussion; but no one could rightly enter upon this study, and still less could therapeutic views be admitted, without a physiological knowledge of the parts in question. These reflections will, I hope, excuse, if they do not justly introduce, the following detached observations; which, I would hope, are almost all appreciable to practitioners of the usual share of attainments.

In the following observations, the safety-valve is considered with reference—

1. To the child at birth &c.
2. To the proportion of safety-valve, as compared with the pulse.
3. To the habits of animals.
4. To the structure in the beaver, the dugong, and the quadrumana.
5. To some apparent exceptions;—in the water-rat, the otter, and the ornithorynchus.

SECT. 1.—OF THE GRADUAL DEVELOPMENT OF THE SAFETY-VALVE IN THE HUMAN HEART AFTER BIRTH, AND THE ANALOGIES IN A SERIES OF THE MAMMALIA.

During the fœtal life of the human being, when the right ventricle of the heart possesses walls comparatively thick and powerful, the action of its valve is pretty certainly most efficient: at a certain time, indeed, the two ventricles seem in all respects equal. When, however, the child begins to respire, and the easy flow of blood through the lungs leaves but little occasion for the exertion of the right ventricle (the ductus arteriosus being in effect closed), the substance and power of this cavity quickly decline\*; while, at the same time, the aortic circulation demands increasing energy in the opposite ventricle, to the nourishment of which the newly-arterialised blood is diverted in a greater proportion. The left ventricle again, on which depend the supplies and development of the whole body, now engrosses to itself all the substance of the septum of the ventricles.

In the first days after birth, the blood is probably little in

\* This decrease may commence before birth; and the cause, I conceive, will be found in a somewhat increasing degree of freedom in the circulation through the lungs.



quantity, and its pabulum is gradually and almost continually supplied; and the infantile movements are, for the most part, gentle as regards the means of hurrying the venous circulation by muscular actions; and we may suppose the right side of the heart to have an easy play, to have no tendency to over-distention, or possibly only some slight and transitory delay. But as age advances, the less frequent and fuller meals, the more sudden and considerable venous repletions, the accumulations in the right heart from general exertions, with occasional delays in the lungs and arterial system arising from the growing activity and augmenting efforts, all conspire to disturb the once-equable current in the right ventricle. It may even happen, perhaps, that this cavity shall sometimes be more engaged in resisting distention than in keeping up the circulation: and I do not doubt, that as diminished calls to exertion lead to feebleness of the part, so rare and sudden fulness will induce dilatation without hypertrophy.

It is very little to admit, that the facts which should carry conviction on these points are not readily at command. My own opinion, however, is, that a fair knowledge of all the established circumstances of the case will not leave room to regard these views as merely hypothetical. I imagine, too, that very palpable facts in comparative anatomy and pathology fully accord with the same explanations. If, besides these successive periodic conditions, it should hereafter be established that the different ages of the adult, and even the sexes, have peculiar adaptations, the result will hardly be more than I have long anticipated.

In examining the foetal heart, I have been led to conclude that its tricuspid curtains, in respect alike of form, adjustment and proportion, are certainly much more completely adapted for a true and strong valvular action than they subsequently become; and the occasional opportunities I have made of trying the operation of the valve experimentally have assisted to corroborate the same conclusion. A safety-valve is evidently not needed for the protection of the lungs at this time; and the regularity of the circulation generally would scarcely allow it to be called into operation, if it existed. I imagine the right ventricle, communicating freely

with the aorta, would even be rendered worse than useless, if its resistance were not in all respects equal to the force which fills that artery.

The comparison of the gradations of the safety-valve in different animals of the class Mammalia, between the rodents and the ruminants, with the gradations described above in the young child, will not fail to furnish a solid argument in favour of the general theory, to those who are prepared to enter into the inquiry. It would only be to repeat my former descriptions, if I were to dwell more at length on these opinions. There is, however, one remark, which deserves a separate reflection; namely, that the morbid dilatation of the right ventricle occasionally carries the parallel between the human and inferior forms one marked step farther. Dr. Hodgkin was accustomed, long ago, to compare the blunt heart of settled pulmonary obstruction in man with the obtuse heart of some of the cetacea; and I think the same will apply, in a measure, to the valve.

SECT. 2.—A COMPARISON OF THE FREQUENCY OF THE PULSE WITH THE DEGREE OF SAFETY-VALVE FUNCTION IN DIFFERENT CASES.

It must be evident, admitting what has just been advanced, that the child after birth, as it gains more and more of a true safety-valve, obtains likewise a slower pulse. It is not intended, however, to maintain that the pulse and the safety-valve action bear a definite proportion to each other: it is only proposed to state a few facts which seem to suggest such a conclusion.

With respect to warm-blooded animals, I conclude it is certainly the case, that as in the whole series (including birds as well as mammalia), the right auriculo-ventricular valve becomes more true and close (as a simple valve), so the pulse increases in frequency. This, as a general observation, will not, I think, ever be controverted: yet it is very possible that some even considerable and striking exceptions remain to be discovered. Enough, however, appears already certain to render the statement a firm basis of reasoning; especially when we compare the facts from the animal series with the statement of the gradational evolutions or gradual increase of the safety-valve, and decreasing number of pulses in the young child.



By reference to a few other circumstances, however, the probable importance of these observations may be made more evident.

Man, submitted to a vegetable diet, especially if the nutrition be of a little-concentrated character, will pretty surely obtain a more copious circulation, and less of muscular firmness: and supposing no peculiarity, as of climate, to counter-vail these tendencies, we should look for rather strongly-marked indications of different habits in various races; and, I conceive, we ought to find every organ manifesting its share of modification, if we were able to appreciate the change.

I conclude plainly, that, with certain limitations, the fuller and slower pulse of a copious, unstimulating diet brings man physically nearer to the state of the ruminants, and *vice versâ*. I do not mean that the pulse depends on the safety-valve essentially for its frequency: the altered nutrition and activity of the left side of the heart may suffice to account for its accelerated or retarded motion. But this I would ask: Is it not a curious and useful object of consideration, if it be true, that the safety-valve continues to correspond with these incidental changes of habit (if I may so speak)? as it certainly does in the permanent states of animals which may be employed to represent the casual conditions of the human body. The answer may be, that remedial and other aims may do without these views; but still it is possible that those aims shall be rendered both surer and safer, by a due regard to these reflections.

It seems to me, that in our reflections on the relation between different kinds of food and states of the heart, of either side or of both sides, we may advance clearly towards a practical knowledge of the susceptibilities of the great organ, both as a whole and a complex organ. I think, too, that the causes of a rapid and firm pulse are the causes of a declining safety-valve; and that the latter is indicated by the firmer and harder pulse. It may not be easy to make these opinions practical; and certainly they are unworthy of the attention of any one, who has not made himself familiar with the details of the theory of the safety-valve. I should not have introduced them without some conviction that, with caution, it may be well applied to the consideration of diathesis and the rise of diseases.

SECT. 3.—ON THE RELATION BETWEEN THE HABITS OF VARIOUS ANIMALS,  
AND THE PROPORTION OF SAFETY-VALVE FUNCTION POSSESSED BY EACH.

Supposing more or less of a safety-valve in a great variety of animals according to their food and habits, it will doubtless appear desirable to give some consideration to the different modes of life which require certain proportions of safety-valve apparatus. I have not thought it my province to make any especial investigation of this subject; and I conceive it will suffice to point out a very few distinct facts, in order rather to explain the nature and value of the inquiry, than to illustrate the extent of its bearing. It will not therefore be necessary to repeat all that has been formerly adduced on the subject.

The rodentia, devoid of any true safety-valve, have a simple stomach, for the digestion of dry or scanty, and sometimes of bitter or stimulating food; and they can scarcely be said to drink. Their circulating fluids are in small quantity. The hare, it is true, is capable of severe exertion; but its aversion to move is at times (of repletion probably) so great, that it will allow itself to be taken with the hand: and it is remarkable, that when hurried, as by the chace, it is subject to pulmonary apoplexy; which is a sufficiently striking proof that its want of a safety-valve renders it less fit to endure widely-varying states of fulness in the right side of the heart.

Feline animals, and others allied to them, with very little more of safety-valve, are scarcely energetic, except in a state of hunger and diminished circulating fluids; whilst repletion renders them materially incapable. The usual drink of a lion, in this country, is less than a pint in the day; but that of a bull, of equal size and from a similar climate, is about a small pailful.

The ruminants have a capacious vascular system and a large digestion. They, too, may need sudden efforts; and I have thought that herding together, and sometimes compressing one another's bodies violently, a sudden afflux must call for the full play of their ample safety-valve very urgently.

In reference to many facts and appearances which will present themselves in opposition to the assumption of strict relation between the habits and the safety-valve of any given



animal, I would refer to a statement which I formerly made, to excuse the use of the term in the case of animals that may seem to have none of the function; namely, I shewed that the right auriculo-ventricular valve acted but feebly or imperfectly in all the mammalia; and I maintained the probability, that, in the closest form of the valve, with the exertion of the animal, the yielding of the annulus and the thin wall of the ventricle would still induce some safety-valve action, when most needed. This argument also favours the opinion, that the true safety-valves must have a free and copious action.

Another reflection seems fairly to connect itself with this. As a safety-valve will require certain correlative adaptations—in the veins, for instance,—so, regardless of external circumstances, we may expect the safety-valve to vary somewhat, in correspondence only with a variation of some internal part or state.

Surely, also, incidental or acquired habits will augment or diminish the ordinary range or degree of safety-valve, if they only affect the dimension and power of the right ventricle. Scanty and nutritious food will induce a limited and firm circulation, as well as an easy respiration, &c.: the ventricles will be small, and their action complete;—and the reverse will obtain. The well-fed gentleman and the trained prize-fighter present a forcible contrast in this matter. The poor man's dog and the pampered creature in the parlour do the same: and I conclude that their hearts participate in the difference; or, where they do not, disease begins.

Lastly, I think that birds are not without circumstances closely parallel to all that we have been considering. It is not to be thought that the over-distended eagle, which is scarcely able to rise thirty feet from its carrion prey, would not be able to fly away with a much larger mass than it has devoured. The obscene birds, as I have observed them, are at times almost paralyzed with repletion; while at other times their power and agility are justly the proverbial type of youth and vigour. I would attribute the oppression almost exclusively to vascular fulness and pressure\*.

\* With reference to habit and the safety-valve, there is still, in comparative anatomy, a new field of observation in the venous and auricular valves. The last, in birds and some mammalia, are very regular and complete structures.

SECT. 4.—NOTES ON THE SAFETY-VALVE OF THE BEAVER, THE DUGONG,  
AND THE QUADRUMANA.*On the Safety-Valve of the Beaver.*

The beaver affords, I think, the simplest illustration and the strongest proof of the theory which it is my aim to advocate. Its heart, contrasted only superficially with that of another rodent, furnishes a conclusion that it will be difficult indeed to controvert; when it is admitted, that variations of form are essential indications of variations of office; and that such a habit as that of diving is to be supported by especial endowments, of one kind or another, external or internal, of altered conformations, or of parts altogether supplementary.

In a former paper, the reader may find described, and drawn, the characters of the tricuspid or safety-valve in the rodentia or gnawing animals. The following is a very marked, and, as far as I know, the only deviation to be found in the form of the valve throughout this order of animals\*.

It will be easy enough to compare the adjoining drawing and sketch; which represent the interior of the right ventricle in the beaver, on the one hand; and in all the rest of the rodentia, on the other. The sketch is from a drawing of the part in the hare which may be referred to in Vol. II. of these Reports. The muscular columns of the valve are all based upon the solid septum; and it is plain that distention

The circular muscles of the caval openings, in many mammalia, and even in man, are not without a use in this respect. The muscular band in man is most marked in the superior cava; and in the dog it is very broad. There are probably other provisions to be considered; but, generally, I suspect that the valves of all the venous system will have distinct and important correlations with the safety-valve. All the so-called imperfect valves act truly or not, as the tube is collapsed or distended. We shall every now and then find such occasions as the following to be provided for. When the seal dives, blood is accumulating in the veins and sinuses of the abdomen; but with the very commencement of respiration, the diaphragm, as it were, empties the abdomen into the chest.

\* I have formerly shewn, that, next to ruminants, the whales, the seals, and (as I suppose) the diving birds, are the creatures most in need of, and most endowed with, a safety-valve in the right ventricle; and I have stated generally—and this deserves full consideration—that the corresponding arrangements of venous and arterial reservoirs, and of venous and other valves, are in pretty regular conformity with the gradations of the safety-valve in the series of warm-blooded animals.



and yielding of the thin wall cannot alter the situation of the bases of the columns, however it may act in dilating the auriculo-ventricular orifice, which the curtain is destined to close more or less completely.

On the other hand, observing the arrangement in the drawing of the beaver, we see the chief muscular columns are secured to the thin wall; which under distention (and it seems very thin and weak) must necessarily draw down the curtains which are connected with these columns, whenever accumulation produces any considerable falling out of the yielding wall. It is observable, that the columns which are thus subject to distention, being widely separated, will also draw the curtains in opposite directions from the plane, in which they close most accurately; and it is to be considered probable that some simultaneous yielding of the auriculo-ventricular orifice serves to increase the passage for reflux.—It only remains for me to ask, Why does this remarkable difference exist? Why is the beaver the only one, among a great variety of gnawing animals (and I have examined a good many), in which any deviation is made in the form of the tricuspid? and why does the peculiarity follow the conformation of other diving animals, and after the manner in which I had hoped to find it?—as I believe the gentleman\* is aware, who sent me the beaver for dissection. I indulge myself with one more inquiry. Can it be for any other reason than this, that, as in so many other cases the suspension of respiration induces a delay in the pulmonary circulation, an arrangement is contrived, by which the impulse of the ventricle should be diverted from the lungs; while its movements may be still kept up, to be in readiness for the occasion, when the inspiration of air will allow the circulation to proceed?

A very little reflection will shew that diving is not the only exigency: and I may here add, that the safety-valve of man is very near, in its main characteristic, to that of the beaver.

\* I am indebted to Mr. Aston Key for this additional and interesting proof of a safety-valve action.



*On the Safety-Valve of the Dugong.*

In my first reference to the safety-valve of the dugong—a vegetable feeder of the whale tribe—I could only surmise that its peculiar double-pointed heart was designed to augment the reflux function to the utmost, to render both the right and left walls of the ventricle subservient to the safety-valve action. I have now to add, that dissection has verified my anticipation.

The following is a description of a Preparation in the Museum of the College of Surgeons. It would be difficult to render it intelligible at first sight; but the reader, who has become acquainted with the account of the parts in the porpoise (as given in Vol. II. of these Reports), may pretty readily comprehend it.

In reference to the safety-valve, I think it is manifest that the right ventricle is, in the most marked degree, thin and yielding; and that the separation of the two ventricles increases its distensibility considerably. No artificial distending force has been exerted upon the ventricle; and it is evident that its walls are collapsing inwards in many parts and not least at those points where the columns of distention are attached. The whole appearance of the right ventricle, though still large, is that of a shrunken cavity.

It does not appear that there is one ("fixed") cord actually inserted into the solid wall: though I may remark, that fixed cords at one point only would interfere very little, if at all, with the forming of an aperture of reflux by distention and general traction of the remaining columns.

The proper moderator band is large and of great extent, though probably here contracted; but its appearance together with a peculiar muscular valve-cord on the first or great column of distention, and also two large bands in the left ventricle) seems very well to illustrate the opinion which I have formerly advanced, that the moderator band is chiefly concerned in regulating the position of the columns of distention.

The inferior attachments of the second and posterior columns of distention point strongly to the inference, that a traction or safety-valve action of these pillars is dependent on their remoteness from the solid septum: and the extended

arch, which two form by uniting superiorly, gives a separate point of insertion to each of their cords, and, at the same time, a different direction to the downward traction exerted upon every one of them at the periods of distention.

*On the Safety-Valve in the Quadrumana.*

The opinion suggested in my first paper, relative to a series of gradations in the safety-valve of different monkeys, has been supported by pretty conclusive examples; and I may add, that the extent to which the variations are carried has exceeded my expectations. In the heart of a baboon (Maimon), prepared by Mr. T. Iliff, I noticed the safety-valve, if it may be so called, at its lowest development. It resembled that of the hare, but still more that of the dog.

It is not unimportant to study the probable result (which I have elsewhere referred to) of the length of the columns of distention. It cannot but indicate some difference, where the muscular column is proportionately thrice as long as in other instances; but I cannot now enter into the inquiry of what constitutes a full or coarse safety-valve (so to speak); and what a delicate or susceptible, though perhaps less free, valve of reflux.

SECT. 5.—OF THE WATER-RAT, THE OTTER, AND ORNITHORYNCHUS; WHICH SEEM TO NEED A SAFETY-VALVE, BUT WHICH SCARCELY APPEAR TO POSSESS THE FUNCTION.

There remains a subject to be touched upon; which I should be very glad to be able to illustrate, not only on account of its interest zoologically, and because it seems to promise curious discoveries, but because, to some, it may seem to furnish objections to the general theory of the safety-valve function.

That there should be exceptions to a rule, is not surprising; nor need we wonder that the interior of animals should at times differ more than their exterior or their ordinary habits. The following peculiarities in the form of the tricuspid are well deserving attention in the way of investigation, both with respect to correlative circumstances of habit, and of conformation in the several animals in which they occur.



The *water-rat* of this country, as far as I have been able to learn, has no peculiarity in the tricuspid, beyond that of the rodentia generally. The tricuspid is a bad safety-valve (if I may so describe it); and like the part in all the rodentia, except the beaver. What compensatory structures may exist, or what states of the animal prevail over the want of a safety-valve, may perhaps be easily discoverable; but it has not been in my power to determine. The suggestions which I have previously made are very likely, however, to involve all the necessary explanation. The digestion of the beaver is more complicated, and probably more copious: that of the rat is most simple.

The *common otter* I have found more devoid of the structure of a safety-valve than some pretty true feline animals. Its valve is like that of a dog. Its thorax is capacious; and it is probably true, that the animal is less of a diver than the seal, except at its periods of fasting.

The *ornithorynchus*\* is another, and the last apparent exception of which I have any knowledge: but of this I still entertain doubts. Its right valve approaches to that of birds and of crocodiles. I cannot speak of any correlative structures or habits that may assist in determining its actions. My conclusion, from the examination of the part in question, is simply, that, like the closest valve of birds, it is designed for a circulation which is scanty in quantity; but that still it may admit of occasional reflux, at least by the dilatation of the annulus, if not by other specific arrangements.

I have not deemed it desirable to enter into anatomical details on the subject of the preceding exceptions, for the same reasons that have deterred me from pursuing the examinations more completely. It seems legitimate for medicine to make use of comparative anatomy; but it is only for the zoologist to give himself entirely to the study. The inquirer may find the parts under consideration displayed in the Comparative Anatomy Museum of Guy's Hospital, together with pretty complete illustrations of the whole subject of reflux function.

\* I have only examined the valve in the *ornithorynchus paradoxus*.





*Fig. 1.*



*Fig. 2.*







